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CHARACTERIZATION AND CONSEQUENCES FROM CEA NUCLEAR FUEL CYCLE FACILITIES EFFLUENTS RELEASES – 1995 UP TO 2007 PERIOD

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ABSTRACT

Discharges to the environment of airborne and/or liquid radioactive effluents from the normal operation of nuclear facilities can become a potential source of radiation exposure to humans. The highest exposed members of the public are defined as the critical group. The requirements for the control and monitoring of radioactive discharges to the environment and the degree of environmental monitoring required are linked to the assessed critical group dose. The assessed dose can be compared to dose constraint, which is a fraction of the annual effective dose to members of the public, as well as the level of exemption specified by the National Commission for Nuclear Energy (CNEN).
Effluents releases from the Centro Experimental ARAMAR (CEA) facilities are registered and described at CEA Effluent Report, semestrally sent to CNEN. Basically, that report provides information related to the type and the quantity of chemical and radioactive substances released to the environment due the routine operation of CEA nuclear fuel cycle facilities (LEI - Isotopic Enrichment Laboratory, USIDE - Pilot Plant for Industrial Verification of Uranium Enrichment and LABMAT - Nuclear Materials Laboratory). CEA Annual Effluent Report includes assessment of the annual effective doses for members of the critical group for the CEA site. This work presents the characterization of the radioactive release source terms and a historical of the critical group annual doses from 1995 up to 2007.

1. INTRODUCTION

The hypothetical critical group of the Centro Experimental Aramar (CEA), located in Iperó, SP, was firstly established in 1997. Since then, revisions and updates have been done to gather and adapt data to best suit the region of interest around the site, which resulted in changes in the methodology used for calculating doses for members of the critical group. It should be noted that the region of interest comprises the 10 km radius area around the CEA, centered in the site meteorological tower (see Fig. 1).

In 2000 [1], annual doses were calculated for the critical group, due to effluents releases from the facilities operating in the CEA, considering the period from 1995 to 1999. In this study, the annual doses are estimated considering the period from 1995 to 2007, using the latest update (see subsection 2.2) of the methodology for dose calculation.

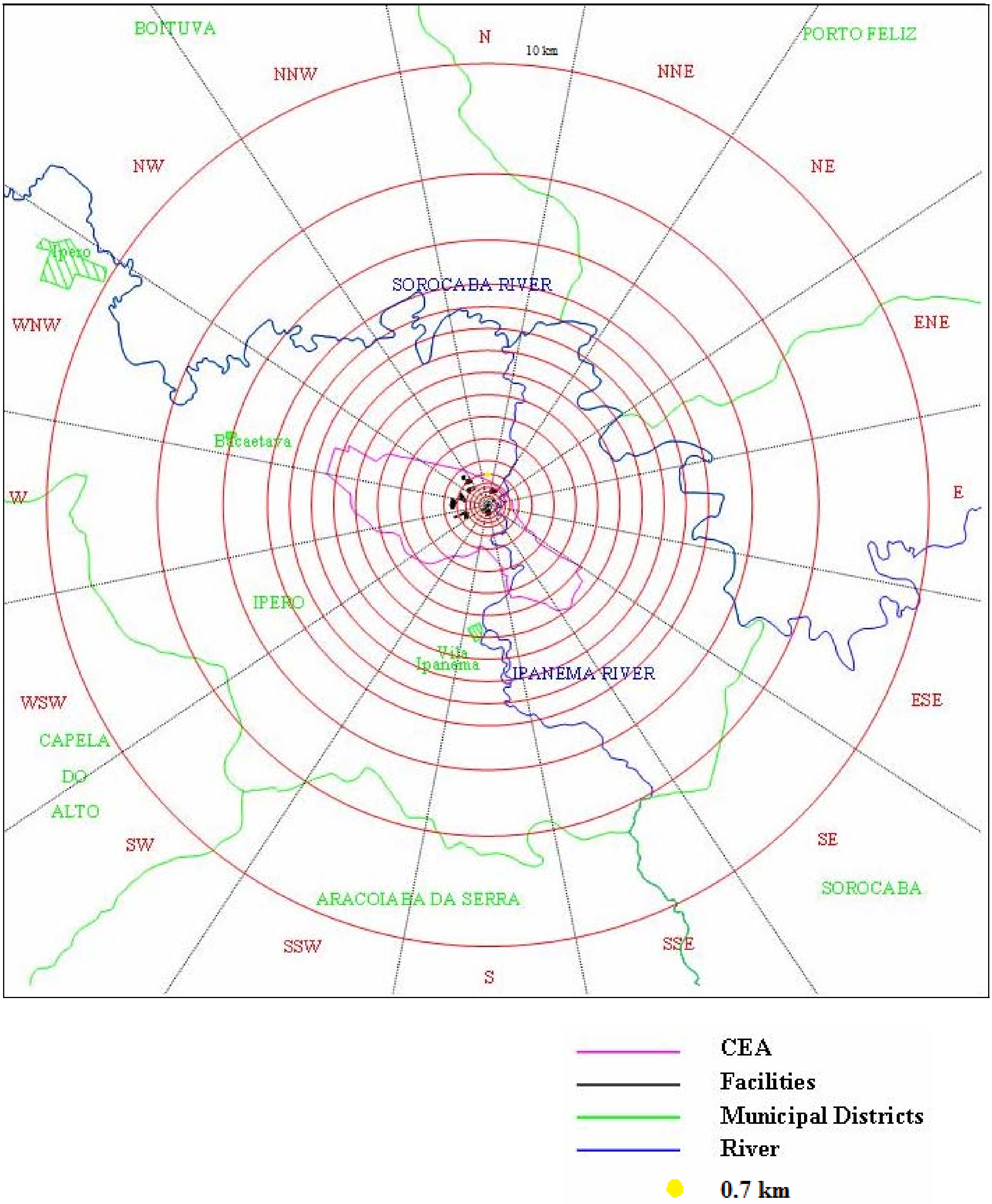

Figure 1. Overview of the interest region around the CEA

The source terms, as described at the CEA Effluent Report (Relatório de Efluentes do CEA), sent semestrally to the CNEN - National Commission for Nuclear Energy (Comissão Nacional de Energia Nuclear), were used to perform the dose assessment. The effluents result from the routine operation of the LEI - Isotopic Enrichment Laboratory (Laboratório de Enriquecimento Isotópico de Urânio), the USIDE - Pilot Plant for Industrial Verification of Uranium Enrichment (Planta Piloto de Demonstração Industrial para Enriquecimento de Urânio) and the LABMAT - Nuclear Materials Laboratory (Laboratório de Materiais Nucleares). Extra activities are also considered, with frequencies that are not fixed, which can also generate additional releases of radionuclides to the environment, e.g., as the washing the empty UF_6 cylinders at LEI.

2. METODOLOGY

To assess the radiological impact resulting from releases of radionuclides to the environment it was used a mathematical model that describes the environmental transfer processes, known as compartments model. This model relates the amount of released radionuclide and equivalent dose received by individuals by using environmental transfer parameters. The methodology of the exposure pathways used to estimate the doses for the critical group of the CEA was based on the work developed by the Canadian Standards Association [2,3], consistent with the methods recommended by the International Atomic Energy Agency [4,5,6,7,8].

2.1. Exposure Pathways

2.1.1. Exposure Pathways for Releases to the Atmosphere

The following exposure pathways were selected related to the atmospheric effluent releases:

- Inhalation: atmospheric diffusion-inhalation.
- Ingestion of Milk, Vegetables, Meat, Pigs, Chickens and Eggs: atmospheric diffusion - deposition of radionuclides on vegetation and soil, contamination of plants via root uptake from radionuclides deposited on soil, incorporation of radionuclides (via inhalation and ingestion of plants) by animals – ingestion of food.
- Deposition on Soil: atmospheric diffusion - deposition of radionuclides on soil - external irradiation.
- Plume Immersion: atmospheric diffusion – plume immersion.

2.1.2. Exposure Pathways for Releases to the Aquatic Environment

The following exposure pathways were selected related to the liquid effluent releases:

- Water Immersion: dilution - immersion in contaminated water.
- Ingestion of Milk, Vegetables, Meat, Pigs, Chickens and Eggs: dilution - ingestion of vegetables contaminated by irrigation; ingestion of meat, milk and eggs via ingestion of contaminated water and irrigated food by animals - ingestion of contaminated food.
- Fish Ingestion: Dilution – ingestion of contaminated fish.
- Exposure to Sediment: dilution - exposure to contaminated sediments on the shoreline of the Ipanema river.

2.2. Assumptions and Considerations

The critical group defined to the CEA is hypothetical and is formed by members of the public who reside or may reside at a distance of 700 m from the release point, at the N sector of wind direction (see Fig. 1).

The methodology used was updated in 2006, which, with respect to that used in [1], can be highlighted the following changes:

a) exposure to sediments on the shoreline of the Ipanema river was considered;

b) the river flow rate is constant and equal to 0,351 $m^3 \cdot s^{-1}$ (minimum flow rate of the Ipanema river);

c) for the effective doses estimative a conservative scenario was adopted, where it is assumed that the members of the critical group receive doses from all pathways of exposure identified in the region of interest (as listed above), regardless of the current existence of such paths in the local defined (distance of 700 m from the release point, at the N sector of wind direction);

d) updated data with respect to the use and occupation of soil;

e) pathways for the ingestion of pork, meat, chicken, eggs and fish were included in the dose assessment; and

f) for the effective doses estimative, beyond the U released, it was also considered the contribution of its short lived daughters, such as ^{234}Th and ^{234m}Pa.

Other considerations accounted for are:

a) in the evaluation of atmospheric diffusion, it is assumed that all gaseous effluents are released at point corresponding to the location of the meteorological tower and they are ground level releases;

b) the liquid effluents generated at the facilities, after treatment at the SITEA - Waste Treatment System (Sistema de Tratamento de Efluentes de ARAMAR), will be released at the same point at the Ipanema river. The river flow rate is considered to be constant and the value used corresponds to the minimum flow rate of the Ipanema river; the flow rate of effluent is also considered constant throughout the year;

c) effective doses were calculated only for adults;

d) uranium contained in the effluents released by LEI and USIDE originated from the compounds UF_6 and UO_2F_2 and are defined as the inhalation class D [9], which was adopted for calculating the doses due to uranium contained in effluents released by LEI and USIDE;

e) uranium contained in the effluents released by LABMAT originated, in most cases, from the insoluble compounds of uranium as the UO_2, classified as the inhalation class Y [9], which was adopted for the calculation of doses due to the uranium contained in effluents released by LABMAT; and

f) U release source terms, provided in CEA Effluent Reports, do not specify the amount of each isotope (^{234}U, ^{235}U and ^{238}U). Thus, the doses were calculated on a conservative basis, using the dose conversion factors that present the highest values for each exposure pathway considered. For example, for doses due to inhalation, the biggest factor is the dose conversion of ^{234}U, so it was considered that the activity of uranium is only released this isotope. Similar procedure was used for other exposure pathways.

3. RELEASES TO THE ENVIRONMENT

The annual quantities of the radionuclides released into the environment, via liquid and gaseous discharges, generated during the normal operation of the facilities LEI, USIDE and LABMAT are provided by CEA Effluent Reports.

Table 1 presents the amount of radioactive material released into the environment via Ipanema river, in the period of 1995 to 2007.

Table 1. Activities of uranium released to the environment, via Ipanema river

Activity Released (Bq)					
Year		**LEI**	**LABMAT**	**USIDE**	**TOTAL**
1995	**U**	1.59E+07(1)	-	-	1.59E+07
1996	**U**	2.15E+07	-	-	2.15E+07
1997	**U**	1.39E+07	1.26E+06	-	1.52E+07
1998	**U**	1.33E+07	5.24E+04	3.90E+04	1.34E+07
1999	**U**	1.49E+07	9.84E+05	6.40E+05	1.65E+07
2000	**U**	6.65E+07	1.33E+05	1.01E+05	6.67E+07
2001	**U**	1.82E+07	1.34E+05	1.11E+05	1.84E+07
2002	**U**	1.29E+07	3.81E+05	1.02E+05	1.34E+07
2003	**U**	9.25E+06	3.58E+05	2.91E+04	9.64E+06
2004	**U**	2.72E+07	5.35E+05	8.06E+04	2.78E+07
2005	**U**	2.36E+07	1.95E+05	1.25E+05	2.39E+07
2006	**U**	2.61E+07	5.13E+05	6.21E+04	2.67E+07
	^{234}Pa	9.91E+07	---	---	9.91E+07
	^{234}Th	9.91E+07	---	---	9.91E+07
2007	**U**	4.54E+07	1.27E+05	6.60E+04	4.56E+07
	^{234}Pa	7.90E+05	---	---	7.90E+05
	^{234}Th	7.90E+05			7.9 0E+05

(1) 1.59E+07 = 1.59×10^7

It should be noted that in 2006 and 2007, the additional releases of the radionuclides ^{234}Th and ^{234}Pa in the liquid effluents were considered, originated from the washing operations of the empty UF_6 cylinders at LEI.

The amount of radioactive material released to the environment, via atmosphere, are presented in Table 2.

Table 2. Activities of uranium released to the environment, via atmosphere

Activity Released (Bq)					
Year		**LEI**	**LABMAT**	**USIDE**	**TOTAL**
1995	**U**	8.44E+04[1]	-	-	8.44E+04
1996	**U**	3.80E+05	-	-	3.80E+05
1997	**U**	4.17E+05	-	-	4.17E+05
1998	**U**	3.43E+04	-	1.00E+03	3.53E+04
1999	**U**	2.48E+04	5.38E+05	1.50E+03	5.64E+05
2000	**U**	9.62E+05	5.96E+05	3.28E+04	1.59E+06
2001	**U**	9.33E+05	1.08E+05	3.31E+04	1.07E+06
2002	**U**	1.06E+06	8.52E+04	2.84E+04	1.17E+06
2003	**U**	1.02E+06	3.40E+04	2.93E+04	1.08E+06
2004	**U**	1.76E+05	1.78E+03	5.00E+03	1.83E+05
2005	**U**	2.18E+05	3.23E+03	8.03E+03	2.29E+05
2006	**U**	2.27E+05	2.56E+03	6.28E+03	2.36E+05
2007	**U**	9.27E+05	2.33E+04	4.69E+03	9.55E+05

[1] 8.44E+04 = 8.44×10^{4}

4. ANNUAL DOSES

Table 3 presents the annual effective doses resulting from the effluents releases from LEI, USIDE and LABMAT, estimated for the critical group of the CEA.

Taking account the additional releases from the washing operation of UF_6 cylinders at LEI, the effective doses resulting from releases of ^{234}Pa in the years 2006 and 2007 are 4.94×10^{-10} and 3.94×10^{-12} Sv, respectively, corresponding to approximately 0.5% and 0.002% of total doses. The effective doses due to releases of ^{234}Th (only for the washing operation of cylinders), for the two years considered, are negligible.

Table 3. Annual effective doses for the critical group of the CEA

Effective Dose (Sv)	
Ano	**TOTAL**
1995	5.18E-08[(1)]
1996	9.74E-08
1997	8.09E-08
1998	3.98E-08
1999	1.66E-07
2000	4.17E-07
2001	1.73E-07
2002	1.66E-07
2003	1.41E-07
2004	9.32E-08
2005	8.84E-08
2006	9.62E-08
2007	2.24E-07

(1) 5.18E-08 = 5.18×10^{-8}

5. CONCLUSIONS

Based on these results, for the release of effluents from installations currently in operation in the CEA, for the period 1995 to 2007, it can be observed that all annual effective doses are lower than 0.3 mSv. This value corresponds to dose constraint, which serves as an upper bound on the predicted dose in the optimization of protection for a given source [10,11]. For public exposure, the dose constraint is an upper bound on the annual doses that members of the public should receive from the planned operation of any controlled source [10]. CNEN [12] recommends the adoption of this value as the maximum dose constraint to members of critical group, related to effluents release and requires an optimization process to set reference release levels.

However, it can be seen that the doses are also lower than 10 μSv (10^{-5} Sv), "in any period of one year". The value of 10 μSv is one of the conditions established by CNEN [13] for the exemption from requirements of radiation protection for a given practice or source associated with this practice. Although a nuclear installation is not released from such controls, the use of this value as a reference level for the discharges of effluents turns the use of optimization procedures unnecessary, in this case, related to the release of effluents from CEA.

It is suggested, for future work, that the recorded values of radionuclides releases should be treated statistically, and can be generated representative (mean) and conservative values (limits values to not be exceeded) for use in studies involving the prediction of consequences (doses, concentrations in the environmental matrixes). These studies will be important to define the optimized operational (reference) levels for the radioactive discharges (to the environment) from the facilities of the CEA, to be considered for routine control of them. Also, considering the new ICRP recommendations [14], it would be relevant to assess doses to the new defined control group for environmental impact assessments, namely, the representative person.

REFERENCES

1. Ferreira, N. L. D., "Doses no Grupo Crítico / CEA Devido à Operação do Lei, da Uside e do Labmat," *Anais do "V Encontro Nacional de Aplicações Nucleares"*, Rio de Janeiro, October 15-20, 2000 (2000).
2. Canadian Standards Association, "Guidelines for Calculating Derived Releases Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities", (1987) (CAN/CSA-N288.1-M87).
3. Lemire, A. E., *Derived Release Limits for Radionuclides in Airborne and Liquid Effluents for the Whiteshell Nuclear Research Establishement*, (1989) (AECL-10028)
4. International Atomic Energy Agency, *Concept and Approaches Used in Assessing Individual and Collective Doses from Releases of Radioactive Effluents*, IAEA-TECDOC-460, Vienna (1988).
5. International Atomic Energy Agency, *Generic Models for Use in Assessing the Impact of Dsicharges or Radioactive Substances to the Environment*, Safety Report Series 19, Vienna (2001).
6. International Atomic Energy Agency, *Principles for Limiting Releases of Radioactive Effluents into the Environment*, Safety Series 77, Vienna (1986)
7. International Atomic Energy Agency, *The Application of the Principles for Limiting Releases of Radioactive Effluentes in the Case of the Mining and Milling of Radioactive Ores*, Safety Series 90, Vienna (1989).
8. International Atomic Energy Agency, *Generic Models and Parameters for Assessing the Environmental Transfer of Radionuclides from Routine Releases: Exposure of Critical Groups*, Safety Series 57, Vienna (1982).
9. International Commission on Radiological Protection, *Limits for Intakes of Radionuclides by Workers*, ICRP Publication 30 (1978).
10. International Commission on Radiological Protection, *The 2007 Recommendations of the International Commission on Radiological Protection*, ICRP Publication 103 (2007).
11. International Atomic Energy Agency, *Regulatory Control of Radioactive Discharges to the Environment,* Safety Standards Series No. WS-G-2.3, Vienna (2000).
12. Comissão Nacional de Energia Nuclear, *Diretrizes Básicas de Proteção Radiológica*, CNEN-NN-3.01, Resolução n^{o} 27, Publicação: D.O.U. 06/01/2005, Rio de Janeiro (2005)
13. Comissão Nacional de Energia Nuclear, *Critérios de Exclusão, Isenção e Dispensa de Requisitos de Proteção Radiológica*, Posição Regulatória 3.01/001, Rio de Janeiro (2005).
14. International Commission on Radiological Protection, *Assessing Dose of the Representative Person for the Purpose of Radiation Protection of the Public and The Optimization of Radiological Protection: Broadening the Process* , ICRP Publication 101 (2006).